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ABSTRACT

This report describes the development of a long-range plan by the Texas State Board of Education for the educational use of technology in Texas schools. The first of four sections of the paper reviews selected research on the effectiveness of technology in grades K-12. The topics addressed are basic skills acquisition; higher-order skills attainment; special education; distance learning; and costs and benefits (the last is deliberately excluded from the long-range plan for technology). The second section presents an overview of economic and educational needs for technology in the state, and discusses the issues of quality, equity, and accountability. The third part suggests research strategies for use in planning for technology, e.g., a review of the research literature on the effectiveness of computer-based and distance learning, or an analysis of statistics on the educational needs in the state that can be at least partially met with the integration of technology. The final section summarizes and describes the status of the State Board of Education's long-range plan for technology for 1988-2000. Topics discussed include: (1) principles of education and technology that have derived from both the content and the ambiguity of the research on effectiveness and needs; (2) key actions proposed for the state and for regional educational service centers; (3) cumulative outcomes expected by the year 2000; (4) the amount appropriated to facilitate implementation of the plan during the first biennium; and (5) the status of the plan as of March 1989. (34 references) (CGD)

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RESEARCH IN PLANNING AND PRACTICE FOR TECHNOLOGY IN TEXAS

Cynthia Y. Levinson

American Educational Research Association
March 27, 1989

OUTLINE

The Paradox of Research and Planning amid Instability

Selected Research Review of the Effectiveness of Technology in K-12 Education

1. Basic skills acquisition.
2. Higher-order skills attainment.
3. Special Education.
4. Distance learning.
5. Costs and benefits.

Economic and Educational Needs for Technology in Texas

1. Economic needs.
2. Educational Needs: Quality.
3. Educational Needs: Equity.
4. Educational Needs: Accountability.

Research in Planning for Technology: Reprise

Summary and Status of the *Long-Range Plan for Technology of the Texas State Board of Education, 1988-2000*

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The Paradox of Research and Planning amid Instability

Like an O. Henry story, planning is an undertaking compelled by irony. If the future could be divined, planning would barely be necessary; at least, it would be easier and more often accurate. Given unpredictability, how and why does an organization plan? To what extent can the future be extrapolated from the present and past in order to guide planning? How useful is research in preparing for the future if the variables are both uncontrollable and changing? These conundrums are particularly troublesome in regard to such volatile areas as technology in which advancements can be explosive and for which even short-term plans can be unravelled by an unanticipated product announcement.

Despite these dilemmas, the Texas State Board of Education, responding to legislation and recognized need, developed, during an 18-month period in 1987-88, a 12-year plan for educational use of technology. This endeavor was tantamount to imagining and planning in 1975 for the proliferation of computer-based workstations and interactive distance learning that had begun to characterize schools by 1987.

The enterprise became manageable, however, as several assumptions and decisions regarding planning for technology were articulated. The first of these was the recognition that planning does not merely take the future into account: planning, to the extent possible, takes charge of the future. In other words, planning can range along a continuum from reactive to proactive, the latter of which the board emphasized.

A paper prepared for the American Educational Research Association in 1984 distinguished between two planning models--long-range and strategic. Drawing on R. Cope, Morrison and Renfro explain that long-range planning focuses on quantitative analysis and trends extrapolation to construct a series of short-range organizational blueprints that reach long-term goals. Strategic planning, on the other hand, focuses on qualitative interpretations of a turbulent external environment to make current decisions creatively and intelligently (Morrison and Renfro, pp. 3-4). As described below, the *Long-Range Plan for Technology of the Texas State Board of Education, 1988-2000* combines these two approaches in order to make institutional decisions based on demographic and economic trends (long-range) while recognizing the multiple independent forces that influence technology development (strategic).

Additional decisions that allowed planning for technology to proceed amid instability included (1) focusing on the functions that technologies can serve in educational settings rather than on technical

specifications; (2) determining the four priority areas of classroom instruction, instructional management, distance learning, and communications; and (3) circumscribing the technologies to those that currently exist in some form. Defining "technology" as "computer-based systems, devices for storage and retrieval of massive amounts of information, telecommunications for audio, video, and information, sharing, and other electronic media devised by the Year 2000 that can help meet the instructional and productivity needs of public education," the plan can incorporate but does not rely on technologies that remain to be invented. These decisions followed considerable discussion on the role of the state in setting standards, including the types of standards (technical or educational) that are appropriate for the state to establish, and on the scope of the vision of education in 2000 which the state should embody.

The broad question of the extent to which planning in rapidly changing fields can or should be based on current and past conditions applies to the role of research in planning as well--a concern of particular import to this Association. To what extent can research conducted in the past under prior constraints inform the future which might be relieved of those constraints or which might be confined by different ones? To what extent should decisions about future technologies and their applications be made based on the results of research on the effectiveness of machinery that is rapidly becoming obsolete or irrelevant? The problem is compounded by the fact that, as headlined in a recent article in *Electronic Learning*, "the research jury is still out" on computers and learning (Bracey, p. 28). Not only are "earlier studies irrelevant" (*op cit.*) in today's more powerful technological environment, but, in addition, those earlier studies yielded ambiguous results.

Thus, the problem is, as we say in Texas, double-barreled. Not only is extrapolation from experience a dubious or limited method of planning in general, but, in addition, experience with technology rapidly becomes immaterial.

Research, however, cannot be disregarded in policysetting. Neither, in a field as diverse and as magnetic to researchers as technology, can it be recounted exhaustively. Following is a selective summary, categorized by the priority topics addressed in the Texas plan, of research on effectiveness of technology in education; where possible, emphasis was placed on meta-analyses rather than on single studies.

Following this section will be a discussion of the researched needs for technology in Texas and, based on these research summaries, a return to the questions of the uses of research in planning. The final section of the paper summarizes and provides a status report on the plan.

Selected Research Review of the Effectiveness of Technology in K-12 Education

1. Basic skills acquisition.

Several meta-analyses indicate that computer-assisted instruction (CAI) generally produces small but significant increases in achievement test scores. The improvement rate varies according to the grade range studied and the application, but, at a minimum, achievement increases from the 50th to the 60th percentile on such tests (Bangert-Drowns, et al, p. 65). Other meta-analyses find improvements from the 50th to the 61st percentile (Kulik and Kulik, p. 224), to the 63rd percentile (Samson, et al, p. 313), and to the 68th percentile (Kulik, et al, p. 59).

Furthermore, according to some analyses,

> Computer-based teaching had its clearest effects in studies of disadvantaged and low aptitude students...This analysis provides the strongest evidence yet available that the computer has an especially positive contribution to make in the education of disadvantaged high school students (Bangert-Drowns, et al, p. 66).

This finding is substantiated by a meta-analysis of past meta-analyses that states, "Six reviews at various grade levels found that slow learners and under-achievers seemed to make greater gains with computer-based methods than more able students (Roblyer, et al, p. 30)." The authors caution that "Many of the studies which yielded high effects with slow learners were of systems designed for this population (Roblyer, et al, p. 30)." More recent analyses, however, have "found no evidence of differences between students on the basis of ability levels (Roblyer, et al, p. 54)." Furthermore, although the conclusion is based only on a few studies, "there was a clear indication...that computer-based instruction with Spanish-speaking populations may not be as effective as other methods (Roblyer, et al, p. 100)." With this important exception, however, this study generally found computers useful in helping students acquire skills.

Other relevant results indicate that "Students learned their lessons with less instructional time," the average reduction being 32 percent, and that students liked both their classes and computers more when computers were used in instruction (Kulik and Kulik, p. 224). A general conclusion of these meta-analyses states that

> CAI (1) has real potential as a tool in improving student involvement in precollege classes; (2) fosters positive attitudes toward the computer; and (3) can produce substantial savings in instructional time...A safe conclusion is that the computer can be used to help learners become better readers, calculators, writers, and problem solvers (Kulik, p. 1).

Studies of programs in Texas corroborate these results. For instance, the Judson Independent School District used a reading and instructional

management system for reading remediation among 35 students. Nineteen of these students, slightly over one-half, scored at or above the 50th percentile and no longer needed remediation.

In addition, commercial learning centers have shown success in increasing literacy and in assisting potential and actual dropouts to acquire certificates of high school equivalency through a computer-based program. The Comprehensive Competencies Program, for instance, provides individualized instruction pursued on a self-paced basis with attainment measured and tracked on computer. The program also provides the ability to diagnose learning pathologies and prescribe remedies. Data indicate that learners have gained an average of 1.1 grades in reading in 31 hours of reading instruction and of 1.6 grades in mathematics in 28 hours of mathematics instruction (Taggart, p. 28). Participants in Adult Basic Literacy Education (ABLE) have increased reading and mathematics skills by an average of one grade level for every 40-50 hours of computer-based instruction combined with tutoring (Mendel, p. 30). Another technology-based program that offers hope to adolescents and adults hampered by a low reading level is Principles of the Alphabet Literacy System (PALS) which uses interactive videodisc. During one 10-week summer session, the reading level of ninth- and tenth-grade students in Florida who were identified as low readers and who met eligibility requirements established by the Job Training Partnership Act rose an average of three grade levels (McGraw, p. 21).

As a result of these successes, a report on workforce literacy produced by the Sunbelt Institute recommends that "Computer-assisted instruction, interactive video disks, television, and other modern technologies must be incorporated more fully into literacy and adult education programs (Mendel, p. 33)." Similarly, a report by the Adult Literacy and Technology Project concludes, "It is imperative...to find ways to make technology, and through the technology, literacy instruction, accessible to everyone (Turner, p. 3)."

2. Higher-order skills attainment.

Higher-order skills can evidently be demonstrably enhanced with the aid of technology. For instance, the average achievement level of junior high school general mathematics students on a standardized test of problem solving rose from the 33rd to the 68th percentile over four years of television instruction (Chu and Schramm, p. 2). The Higher Order Thinking Skills (HOTS) Program developed by Dr. Stanley Pogrow of the University of Arizona shows gains in thinking skills and social interaction that continue beyond the experimental experience. In the HOTS program, commercially available software is used to develop in at-risk students the thinking skills of metacognition, inference, decontectualization, and synthesis. As conceived by Pogrow, the HOTS program "is an alternative to Chapter I programs in grades three through six that replaces all compensatory content instruction and drill and practice with thinking skills activities (Pogrow, p. 11)."

Results of the program, as reported by Pogrow, indicate that, "in addition to gains in thinking skills and social interaction, schools are generating gains exceeding 15 percentile points (reaching as high as 25

percentile points) on standardized tests the first year. Gains continue in the second year. Standardized math scores are also up substantially without specific math activities the first year. Indeed, HOTS students have been outperforming students in computerized drill and practice programs (Pogrow, p. 11)."

Pogrow emphasizes that it is not the computer alone that is responsible for these successes. The technology is a tool that must be used with the HOTS curriculum, teaching techniques employed by trained teachers, and instruction in the regular curriculum. He explains that "the key to using computers to enhance learning in transferable ways is not the computers or programs themselves but the dialogue that ensues between teacher and students (Pogrow, p. 13)." He further cautions that "simply using thinking software, word processors or the computer as a general tool will primarily benefit high-performing students who have already internalized procedures for generalizing and linking ideas. In the case of at-risk students, special, intensive techniques need to be developed to promote internalization of key basic thinking process before they can benefit measurably from sophisticated applications integrated into content (Pogrow, p. 15)."

3. Special education.

Special needs students, those with physical and mental handicaps, can in many cases be reached more effectively through technology than with only teacher-student contact. "Adaptive/assistive devices" can compensate for sensory communication, mobility, and manipulation deficits. Technological examples of such devices include braille writers and printers, speech synthesizers, reading machines, and eye movement detectors. Project ACTT (Activating Children Through Technology), for instance, integrates microcomputers with speech and music synthesizers, graphics tablets, and other devices, into educational programs for mildly to severely handicapped children to the age of eight years. Preliminary results indicate that computer use increases attention span, retention, social interaction, and aspects of problem solving (Hutinger, p. 5).

A preliminary research project at the University of California at Los Angeles indicates that using speech synthesizers with adolescents with Down's syndrome increases the teenagers' speaking, reading, and writing abilities. Within 10 sessions, more than 80 percent of the students gained at least six months in mental age on at least one-half of the standard tests (Kolata, p. 15).

Videodisc technology for instruction and management developed at Utah State University has been shown to be effective in teaching some content, such as telling time, and skills, such as social interaction skills, with children with mild intellectual handicaps (Hofmeister and Friedman, pp. 360-361).

Technologies can be effectively used to assist management and diagnosis of special needs students as well as to support their instruction. Several programs exist, for instance, that periodically list children due for Individualized Education Program (IEP) review and automatically

report necessary data to state and other agencies (Bennett, p. 107). Preliminary evaluations of expert systems to diagnose handicapped students as learning disabled indicate that the expert system's conclusions "were comparable to those of the 'better' human experts and more acceptable than those of the majority of human experts (Parry and Hofmeister, p. 131)." Similar studies of the use of expert systems to diagnose reading problems "revealed that the expert system provided more detailed information than human diagnostic reports (*Ibid.*, p. 130)."

4. Distance learning.

Studies of distance deliverers of instruction generally indicate that students enrolled in distance learning programs exhibit achievement and motivation at least as high as those shown by students in traditional settings. Research cited in the Texas plan focuses on instructional television and some other forms of telecommunications-based technologies; other vehicles, including radio and mail, have also proven successful. Perhaps because of the enchantment cast by computers and related telecommunications technologies that have recently become readily available in public school education, current research on instructional television, unadorned by interactivity or computer enhancement, is sparse. Dating from 1975, the research on instructional television cited in the plan is venerable.

In regard to the application of newer computer- and telecommunications-based technologies to distance learning, two major assessments are cited in the plan--a pilot evaluation project conducted by the Texas Education Agency of delivery by distance of courses for credit in 1985-86 and Minnesota's Technology Demonstration Site program. The TEA study evaluated delayed videotaped Spanish courses (which were noninteractive in 1985-86), courses in German I and Psychology provided by Instructional Television Fixed Service (ITFS), and Computer Science I, French I, and Psychology provided by satellite; the latter two systems were live one-way video and two-way audio. The evaluation concluded that:

* Overall mastery demonstrated by program students was equal to or better than mastery by comparable students in the traditional classes.

* Test scores suggest that these highly cost-effective services provide a good alternative source of instruction in cases where on-site teachers cannot be provided.

* Students feel that telecourses require more effort than traditional courses.

* Both telecourse and traditional teachers tended to rate their own courses positively.

* Most parents were favorable in their general opinions of televised courses.

Opinions of students and parents were positively related to the level of interactivity represented in the particular telecourse medium, with

videotaped courses at the least interactive end of the scale and satellite and microwave at the most interactive end of the scale . This finding supports the importance of the teacher-student relationship suggested in other studies.

Another example of successful uses of technology to deliver curriculum to remote districts is the Technology Demonstration Site (TDS) program created by the Minnesota Education Technology Act of 1983. A wide variety of technologies is used in TDS schools, including in-class computers and two-way television for distance learning and inservice.

Findings of the Technology Demonstration Sites indicate that the instructional effect of these technologies is positive. To quote the Final Evaluation Report of the Technology Demonstration Site program,

> Technology has a high degree of perceived value and impact: virtually all of the large number of educators interviewed, surveyed or otherwise tested during this evaluation believe that technology, particularly computers, provides significant learning advantages. The data suggest that some applications of technology, namely interactive television, do provide advantages and do not measurably affect either classroom "climate" or academic achievement (Morehouse, Hoaglund, and Schmidt, 1987a, p. 5).

5. Costs and benefits.

Cost-benefit analysis, while animatedly discussed and conscientiously researched during the planning process, is not included in the Texas *Long-Range Plan for Technology*. The decision to exclude it was made despite the assertion of the National School Boards Association in a report on the transfer of technology to education that "We cannot improve the productivity of education if we don't know what it is, and that requires accepted measures of performance and cost...'[N]o measure' is the worst of all possible worlds (Perelman, p. ES-14)."

The fundamental reason for omitting from the plan a discussion of cost benefit relates, paradoxically, to the capabilities of the technologies. Interactive learning systems and other empowering technologies that will diagnose learning styles, individualize pacing and teaching approaches, and provide access to information previously unavailable to students are likely to promote educational achievement that is unattainable in any other way. The relative benefit of delivering individually-needed curriculum, of providing physically handicapped students with communications media, of early detection of at-risk status, of conveying concepts according to particular thinking styles is, at best, difficult to quantify in the absence of an alternative. What is the value to a community or the state of providing international news, data, and primary sources to a geographically isolated student who, without access to telecommunications technologies, would be unaware of the existence of such information, let alone its content? What is the value of simulating potentially explosive chemical experiments that would otherwise be barred from the curriculum? While the relative cost per measure of learning gain of basic skills imparted by computer-assisted

instruction as opposed to other strategies can be computed, the value for cost of providing otherwise unattainable skills and inaccessible knowledge is incalculable.

Comparing computers with other learning tools in their contributions to increasing speed or level of attainment assumes that it is the current curriculum and skills that are the desired outcomes. The main value of computers and other technologies lies in their abilities to promote new activities and skills, the benefits of which may not be measurable by current techniques or comparable to currently valued outcomes. Both Pogrow and Linn have asserted a similar position (Stern and Cox, pp. 15-18).

The integration of technology is likely to induce changes not only in curriculum and instruction but also in school management. As stated in the Texas plan, management and structure will evolve as evolving technologies are implemented. To date, these projected alterations have not entered the cost-benefit equation.

An additional reason that a review of the research and a position on the cost effectiveness (considered interchangeably here with cost-benefit) of technology are not included in the plan is that, although publications on the topic are plentiful, many either focus on the importance of conducting an analysis or provide guidelines for doing so rather than actually supplying data. Furthermore, some testimonials rely on hypothetical projections rather than on rigorous comparisons with limited variables. As a result, the developers of the Texas plan concluded that cost-benefit analyses of technology in education are, as yet, neither persuasive nor sufficiently informative to contribute to decisionmaking.

For the sake of completeness, however, and in response to a request by a reviewer of the proposal for this paper, a summary follows of key citations that would have been reviewed had such a discussion been included in the plan. It is divided into two sections--(1) methods and issues of analysis and (2) data-based studies.

The most extensive and cogent issues analysis was prepared by David Stern and Guy Cox for the Office of Technology Assessment. Pogrow, Linn, and the Texas Education Agency notwithstanding, Stern and Cox argue for the utility of cost-effectiveness studies of computers on the grounds that "the exciting future potential of computer-based programs in education does not diminish our concern for careful use of resources to achieve current purposes (Stern and Cox, p. 18)." (They also distinguish between cost effectiveness, which addresses "whether schools produce the maximum amount of student learning, given limited budgets," and cost benefits, which addresses "whether the monetary value of benefits from education exceeds the amount of money spent on it [Stern and Cox, p. 13].")

After explaining methods of cost-effectiveness analysis and reviewing experimental studies, the authors discuss the factors that need to be considered in conducting such studies and in using them as bases for decisionmaking. These factors are (1) the utility of current outcome

measures, given the changes in the process and purposes that computers are likely to cause in education, (2) the difficulty of isolating the effects of computers on education, (3) the complexity of analyzing effectiveness when multiple outcomes occur, (4) the political decisions that enter when weighing the relative importance of various outcomes ("cost utility"), (5) the fact that increases in computer power and decreases in computer cost precede the publication of research results on cost effectiveness, (6) the question of whether computers are an add-on or a replacement, and (7) the problem of software production and distribution.

Arthur Melmed proposes an additional factor--cost distribution. He suggests that public expenditures for education will decline because of early graduation and that some costs will be absorbed by families, as they purchase computers for home learning, and by the federal government and the private sector, as they take increasing responsibility for research and development (Melmed, p. 81). Consistent with this general emphasis on cost rather than effectiveness is that of Pogrow who in 1983 projected that "by the middle of this decade the new technologies...will have compelling labor substitution potential (Pogrow, p. 79)." Given the resulting structural changes in education, "then a shift from effectiveness-based to cost-based policies is feasible (*ibid.*, p. 80)." Randall and Spuck, however, who, like Stern and Cox, discuss factors of cost effectiveness, state, "ultimately the effect of a program is of more import than cost, since if there is no effect the program is of no value, regardless of cost (Randall and Spuck, p. 333)."

Empirical studies of cost effectiveness manifest ambiguous results. Comparing four interventions to raise mathematics and reading achievement at the elementary school level, Levin and Meister with Glass conclude that "despite vigorous assertions that CAI is more cost-effective than other instructional interventions, little or no evidence exists to support this notion (Levin and Meister, p. 747)." They found that, based on "months of additional achievement gain per year of instruction,"

> the specific CAI intervention we evaluated was more cost-effective than adult tutoring, reducing class size, or increasing instructional time. However, it was considerably less cost-effective than peer tutoring in mathematics and slightly less cost-effective than peer tutoring in reading. This suggests that, though CAI is a relatively cost-effective intervention, it is not necessarily the most cost-effective approach to improving mathematics and reading achievement in the elementary grades (*ibid.*, p. 749).

Measuring "cost per month of grade placement gain per student" in elementary school mathematics instruction, Hawley and others found, on the other hand, that "adjunct microcomputer-assisted mathematics instruction was found to be more cost effective than traditional mathematics instruction (Hawley, et al, p. 31)." Unlike Levin and Meister's study, Hawley's did not compare a variety of methods of traditional instruction.

Cost analysis of individualized instruction, including use of computers, in a non-traditional setting also supports Hawley's conclusions. In testimony before the Senate Committee on Labor and Human Relations, Taggart states that "the cost per reading grade gain achieved by CCP [Comprehensive Competencies Program] learners has averaged only $350, and the cost per math grade gain only $250, roughly half the cost per grade gain in traditional programs (Taggart, p. 41)." Taggart's position is based, in part, on data on the social and economic costs of students' leaving school early and their attendant depressed basic skills, a concern by no means less important but significantly broader than those analyzed in a controlled experiment. Furthermore, CCP incorporates a variety of individual instruction techniques in addition to computer-assisted learning.

Drawing on and extending the work of Stern and Cox, the Office of Technology Assessment devotes a chapter in *Power On!* to cost effectiveness. Among its citations of empirical studies is an investigation conducted by the Institute for Defense Analysis which found that both computer-assisted instruction (CAI) and CAI combined with computer-managed instruction cost approximately one-third less per unit of effectiveness than traditional instruction (U. S. Congress, p. 78). The report notes that, although these results do not necessarily pertain to elementary and secondary education, "they do demonstrate the value of explicitly accounting for the costs of various modes of instruction (*Ibid.*)."

As indicated by the differences exemplified by Melmed, on the one hand, and Randall and Spuck, on the other, this proposition is open to question. Not only is the research on cost effectiveness and costs and benefits limited and ambiguous, the place of any definitive results in policymaking also remains unclear.

Economic and Educational Needs for Technology in Texas

1. Economic needs.

According to former Secretary of Labor Ray Marshall, "there is a positive relationship between education or schooling on the one hand and productivity, economic growth, and personal incomes on the other....Education can greatly improve industrial and social economic performance (Marshall, pp. xix and xxiii)." Based on this argument (which is well documented in a two-volume set of research papers prepared in conjunction with the plan by Dr. Marshall and his students in a seminar on "Education, Technology, and the Texas Economy" and which was also articulated by members of the Commissioner's Advisory Committee on the Long-Range Plan for Technology), the agency investigated both economic and educational needs during the development phase of the long-range technology plan.

These investigations revealed sobering data on the Texas economy and on the concomitant need to pursue educational reform in the state. The

former foundations of the Texas economy--oil, agriculture, and labor-intensive manufacturing--have deteriorated ominously during the current decade. For example, from 1982 to 1987,

* Employment in oil and gas production fell 40.2 percent, from 303,200 jobs to 181,400; employment in these areas, formerly as traditional to Texas as cowboys, dropped from 4.8 percent to 2.8 percent of all jobs in the state (Texas Employment Commission, n.d., pp. 1-2).

* Agricultural employment dropped 26.1 percent, from 253,000 to 187,000 jobs (U. S. Department of Labor, Bureau of Labor Statistics, 1982-1987).

* In manufacturing, employment fell 11.2 percent, from 1,045,200 jobs to 928,300 (Texas Employment Commission, n.d., pp. 1-2). While actual employment in Texas is projected to grow, the manufacturing share of total employment is projected to continue to decline from about 30 percent to 25 percent by 2000.

Although employment is decreasing in such traditional Texas industries as oil, agriculture, and manufacturing, there is evidence that employment in other sectors, specifically services, is increasing. Data for total United States employment indicate that goods-producing industries will show almost no aggregate employment change while service-sector employment will account for almost all of the projected growth through the Year 2000 (U.S. Department of Labor, Bureau of Labor Statistics, 1987, p. 3). Employment trends in Texas are projected nearly to parallel those of the nation. The service sector will experience a 27-percent growth rate during this period generating close to 70 percent of total job growth. As a result of this growth, the service sector will comprise one-third of all nonfarm salaried jobs by 2000 compared to about 22 percent in 1987 (Texas Employment Commission, 1988, p. 26).

Disaggregated by subsector, the service economy in Texas is projected to experience by 2000 a 52-percent increase in business services, 48-percent increase in health services, 44-percent increase in computer and data processing services, and 38-percent increase in need for teachers and instructors (Texas Employment Commission, pp. 29-37).

These employment shifts will have profound implications for education for many of the occupational groups experiencing faster-than-average growth will require the most educational preparation. These occupational groups include executive, administrative, and managerial workers, professional workers, and technicians and related support workers.

2. Educational Needs: Quality.

As part of the implementation of the legislated education reform movement in Texas, the State Board of Education adopted a *Long-Range Plan of the State Board of Education for Texas Public School Education, 1986-1990*. The mission of this plan includes the following tripartite statement:

- Instruction must be provided at the highest levels of quality.

- Educational opportunities and resources must be distributed with equity for all students.

- The educational system must maintain accountability for demonstrated results and continuous improvement.

Based on these missions, the educational needs for technology were investigated and are organized in the technology plan according to these components. A brief overview follows.

While improving, educational quality has room to grow in Texas. A scan of the results of the Texas Educational Assessment of Minimum Skills (TEAMS) indicates that an increasing percentage of students in Grades 3, 5, 7, and 9 has passed all TEAMS tests taken during the past three years. Nevertheless, an achievement gap, though decreasing, persists between Black and Hispanic students and their white counterparts both at these grade levels and, increasingly, at the exit level. (More extensive data on these tests are cited in the *Long-Range Plan for Technology* and are available in full in *Texas Educational Assessment of Minimum SKills: Student Performance Results, Volumes 1 and 2*). Results on the Scholastic Aptitude Test (SAT), on which the average scores of Texas seniors trail those of the nation, also reveal a need for a higher quality educational program. As indicated in the section above on selected research, technology holds promise for improving some of the basic and higher-order thinking skills that are required of students for success in school, on these tests, and in life-time achievement.

In addition to lagging scores, teacher supply and demand projections also indicated a need to address educational quality in novel ways. While supply and demand are projected to remain in balance until 1991-92, a survey of sample districts revealed shortages in specific curriculum areas.

* 89% of sampled districts report at least some shortage of bilingual education teachers.

* 71% show a shortage of special education teachers.

* 50% show some to extreme teacher shortages in mathematics, science, and pre-kindergarten (Aki, p. 4).

These shortages are most likely a result of mismatched location of supply and demand.

These shortages are likely to be exacerbated in the 1990s. The number of initial teacher certificates issued by the state has dropped every year since 1982-83 for an overall reduction in certificates of 41 percent between that year and 1986-87. In addition, between 1984-85 and 1985-86, the number of provisional certificates issued by Texas institutions in such high-need areas has plummeted.

DECLINE IN PROVISIONAL CERTIFICATES IN SELECTED AREAS
1984-85 and 1985-86

Bilingual Education	-52%
Physically Handicapped Education	-41%
Composite Science	-34%
Kindergarten	-28%
Mathematics	-12%

Through emergency permits and other means, only four percent of vacancies remain unfilled. Thus, disturbing as these figures are, the numbers of teachers needed to fill classrooms mask the greater issue--that of quality. As revealed by earned degrees, Texas teachers have attained a lower level of education than teachers nationally; over one-half of the teachers in the United States have received a master's degree, while only one-third of Texas teachers have earned this degree. Furthermore, students in districts that are small, of below average wealth, or that have a high percentage of Black, Hispanic, or low-income students are less likely to be instructed by teachers with a master's degree and are more likely to receive instruction from teachers with a bachelor's or no degree than are other students.

Again, as suggested by the research, computer workstations and distance learning offer strong hope of addressing the problem of the shortage of masterful teachers.

In order to help improve classroom teachers' pedagogical and management skills, Texas requires extensive inservice training. Each of the more than 180,000 teachers in Texas is required to participate in a minimum of four days of inservice each year and, in order to advance on the Teacher Career Ladder, to participate in additional college work and/or in up to 135 hours of Advanced Academic Training (AAT). In addition, up to 12,000 administrators must receive thorough and uniform training in teacher appraisal during 1989; each of the nearly 15,000 administrators in Texas is required to participate in General Management Training in 1989-90; and, based on appraisal results, each of the 15,000 must also participate in continuing training annually thereafter.

As a result of these and multiple other teacher and administrator training needs, the long-range technology plan incorporates statewide telecommunications systems.

3. Educational Needs: Equity.

Equity can be defined in many ways. One set of definitions has been developed, at the time of this writing, by the courts and the legislature through *Edgewood v. Kirby*, the case that questioned the constitutionality of the school finance system in Texas. In the *Long-Range Plan for Technology*, the concept encompasses equitable access to instruction and equitable access to information and information technologies. Data indicate that Texas schools and their students fall short in both areas.

State Board of Education rules for curriculum require districts to provide a minimum number of specified courses at least every other year so that students can take the required curriculum. Data on course enrollments indicate that some districts may be unable to meet these requirements.

Of 983 districts showing membership in the ninth, tenth, eleventh, or twelfth grades in 1985-86 and 1986-87,

* 656 districts (66 percent) did not show enrollment in at least one of the English courses which districts are required to offer. Of these districts, 548 did not show enrollment in either Composition or British Literature.

* 237 districts (24 percent) did not show enrollment in at least one of the mathematics courses which districts are required to offer.

* 214 (22 percent) did not show enrollment in at least one of the science courses which districts are required to offer.

* 42 districts (4 percent) did not show enrollment in any foreign language course; an additional 124 districts did not show enrollment in the two levels of the same foreign language which districts are required to offer.1

In addition to lack of enrollment in required courses, significant differences exist among districts, by various characteristics, in the average number of courses offered. As the following tables reveal, the six largest districts offer an average of almost four times as many courses as do the nearly 400 smallest districts. Even those districts with a population of fewer than 5000 students offer an average of nearly twice as many courses as do the smallest districts. Similarly, students in rural schools can select among only approximately one-quarter of the courses offered to their city cousins.

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1 Because the Public Information Management System (PEIMS) was not yet implemented during the development of the *Long-Range Plan for Technology*, the data source indicates enrollment, not whether or not districts offered courses. Lack of enrollment does not necessarily signify failure to offer a required course since eligible or interested students may not be available to take all required courses in every district in a given two-year period. Anecdotal evidence suggests, however, that some students, particularly at small districts or campuses, are denied appropriate course work because of a lack of critical mass, a problem that can be overcome with increased access to technology.

AVERAGE NUMBER OF COURSES OFFERED
BY DISTRICT SIZE
1985-86 and 1986-87

District Size (Average Daily Attendance)	Number of Districts	Average Number of Courses Offered
50,000- Over	6	208.83
25,000-49,999	14	173.57
10,000-24,999	43	147.74
5,000- 9,999	41	117.63
3,000- 4,999	91	105.01
1,600- 2,999	114	83.89
1,000- 1,599	124	76.10
500- 999	205	69.26
Under- 500	399	53.78

Source: Texas Education Agency

The average number of courses offered also varies considerably by type of district.

AVERAGE NUMBER OF COURSES OFFERED
BY DISTRICT TYPE
1985-86 and 1986-87

District Type	Number of Districts	Average Number of Courses Offered
Major Urban	8	200.38
Major Suburban	61	134.20
Other Central City	23	148.13
Independent Town	67	101.52
Other Central City Suburban	72	96.88
Non-Metropolitan Fast Growing	154	71.88
Non-Metropolitan Stable	210	78.35
Rural	442	55.60

Source: Texas Education Agency

Particularly disturbing is the disparity of courses offered according to the percentage of low-income students living in districts.

AVERAGE NUMBER OF COURSES OFFERED
BY PERCENTAGE OF LOW-INCOME STUDENTS
1985-86 and 1986-87

Percentage of Low-Income Students	Number of Districts	Average Number of Courses Offered
Under 20%	235	84.50
20% to under 30%	207	75.97
30% to under 40%	217	76.63
40% to under 60%	229	71.44
60% to under 80%	107	70.70
80% and over	42	69.95

Source: Texas Education Agency

Fully 93% of the districts in the state, representing 44% of total Average Daily Attendance (ADA), offer fewer than the median Average Number of Courses Offered of 131.31.

Just as courses are offered and subscribed to at differential rates across the state, so are technologies available inequitably. The density of computer availability ranges from one computer for every six students in some districts to one for every 95 students in others (Hayes, pp. 168 and 192-96). In addition, of the 213 districts that reported in 1985 that they did not use computer services for administration, 80 percent were small, 74 percent were rural, and 60 percent were of below average wealth.

4. Educational Needs: Accountability.

The recent emphasis on accountability for public agencies, though necessary and probably inevitable in the face of increased reform and funding, has produced a secondary effect of exacerbating the reporting requirements that already constituted heavy burdens on schools. The Carnegie Foundation for the Advancement of Teaching reported that 52 percent of teachers nationwide noted increased paperwork burdens during the past five years (Carnegie Foundation for the Advancement of Teaching, p. 59). In Texas, the proportion reached 61 percent. In fact, despite paperwork reduction efforts in the state, a 1987 survey of Texas teachers found that approximately 72 percent of teachers reported spending over 7 after-school hours per week on paperwork which they cited as the primary source of teacher frustration (Lutz and Maddirala, pp. 3-22).

As technologies of various configurations can address issues of educational quality and equity, so can they alleviate teacher and administrator management duties by automatically conducting tracking, inventory, computing, reporting, and other such chores.

Research in Planning for Technology: Reprise

To return to the initial questions regarding the role that historical research can play in planning for metamorphosis: Two types of research were conducted in developing the Texas *Long-Range Plan for Technology*--(1) a review of research literature on the effectiveness of computer-based and distance learning and (2) an analysis of statistics on the educational needs in the state that can be at least partially met with the integration of technology. These two types of research are used differently in the plan, in keeping with Morrison and Renfro's distinction between long-range and strategic planning.

Despite the rapid obsolescence of many studies and the ambiguity or contradictoriness of their results, the literature review provides general support for the proposition that technology can improve education. A positive, data-based depiction emerges of the role that technology can play in raising achievement, expanding the communications and intellectual skills of special education students, extending the curriculum to isolated students, and lowering costs and increasing efficiency in communications. This research, notwithstanding its limited utility to inform us about the effectiveness of the machines of the future, lays the groundwork for strategic policymaking.

The interaction between research and the policies encompassed in the Texas technology plan is suggested in the section above on cost-benefit analysis. As noted in the discussion, this topic was excluded from the plan because of insufficient data and uncompelling conclusions, but it was not excluded from investigation during the planning process. The planning process, like a comprehensive, non-policy assessment such as *Power On!*, must be inclusive, while the resulting document is selective. The selections must be made with integrity, though, so that the research influences the policies more than the other way around.

The Texas-specific data fill in the background provided by the research overview with the particular needs for technology in the state and, therefore, with the technologies' required functions and applications. This information, in turn, propels the plan; that is, it helps determine the responsibilities and the timelines for integrating the applications. This research, then, is used to make the specific long-range policy decisions and assignments.

The vexing problem, however, of deciding in which particular machines (in other words, in which software, courseware, functions, configurations, learning and work styles, and training) to invest persists since new products, applications, and capabilities appear frequently (although, if one surveys the field, not entirely unexpectedly.) Combined, both types of research suggest, paradoxically, that technology should be integrated into education promptly in order to make the latter more efficient and effective but that doing so inevitably occurs too soon. Research is a necessary-but-not-sufficient ingredient in long-range strategic planning for technology. While it cannot determine the future, regardless of the extent of the planners'

proactiveness, it properly colors the policymaking, which, in circular fashion, culls the final research base.

A common planning paradigm states, "envision the future and work back to the present." While proactive, this approach has limited utility when the vision is prey to unimaginable changes, such as those occurring in the world of technology, and when accomplishment of the vision relies on factors beyond the scope of the plan, such as economic shifts or the actions of tangential institutions. Long-range strategic planning for technology is not a closed system whereas research methodology necessarily limits the variables. The research can indicate answers to finite questions, but planning for technology use in education will, nevertheless, be forever turbulent.

Summary and Status of the *Long-Range Plan for Technology of the Texas State Board of Education, 1988-2000*[2]

As stated above, the research guided, even if it did not dictate, the actions allocated in the plan to designated responsible entities. These actions are based on a set of principles regarding education and technology that derived from both the content of the research on effectiveness and needs and, paradoxically, from the ambiguity of the research as well. These principles state:

* Technology must be infused into instruction: technology is, by definition, a tool.

* Technology is one of many vehicles that must work in concert with one another for improving education.

* Districts and campuses must be accorded flexibility in selecting technologies and applications to meet local needs while being held accountable for continual improvement in achievement and productivity.

* State and local governments must provide incentives for technology acquisition and implementation.

* Teachers are essential for high-quality education.

* Staff training is critical to successful integration of technology.

* Future decisions must be based on the results of research.

* Technology changes rapidly and unpredictably, and technology changes the settings into which it is incorporated. The plan, therefore, is flexible in the long term, able to incorporate a variety of technologies and to take advantage of the multi-vendor environment. The education system must also be flexible, able to revise

2 The entire *Long-Range Plan for Technology* may be purchased from the Publications Distribution Office, Texas Education Agency, 1701 North Congress Avenue, Austin, Texas 78701-1494.

assumptions as technology contributes to changing the current educational environment.

Actions. The calendar for implementing the plan is divided into three phases of four years each. Key actions proposed for the state during Phase 1 (1988-89 through 1991-92) include:

* Authorize expenditures and other legislative changes for implementation of the plan.

* Establish a technology equipment allotment within the Foundation School Program of at least $50 per student per year on an equalized basis for district hardware and courseware and facility modification.

* Reinstate support for instructional television.

* Establish a statewide electronic information transfer system.

* Establish a research and development consortium and demonstration programs.

* Expand distance learning by building on available services, including public broadcasting and other providers.

* Assist districts with selecting and acquiring equipment through revising arrangements with the State Purchasing and General Services Commission.

* Incorporate courseware adoption into the textbook adoption process.

* Revise curriculum rules.

* Support teacher and administrator training in and by technology.

* Establish quality, technical, functional, security, service, and other standards for equipment, courseware, and training through a State Board of Education Advisory Committee on Technology Standards.

Key actions proposed for regional education service centers emphasize:

* Establish Technology Preview Centers.

* Include in core services training and other assistance to districts in technology selection and use.

* Employ at least 1 full-time equivalent at each regional education service center to perform these functions.

Key actions proposed for districts during Phase 1 include:

* Prepare annual district and campus plans for technology.

* Provide training to staff in appropriate uses of technology.

* Provide incentives for staff to use technology.

* Procure and integrate hardware and software according to local plans and State Board of Education Equipment Targets.

* Use integrated telecommunications systems for instruction, inservice, and information sharing.

* Participate in demonstration programs.

Institutions of higher education are called on to incorporate technology in undergraduate and graduate instruction and training and to conduct and disseminate research in educational uses of technology. The consortium will, during Phase 1, initiate research projects for value-added development and marketing by member companies of educational applications of technology. Actions by these entities during the subsequent two phases pursue those initiated in the first phase to reach the following cumulative outcomes. Interim outcomes of actions are stated in the calendar.

Cumulative Outcomes. Procedural and interim outcomes will take place during the early phases. By 2000, the cumulative outcomes are expected to include:

* Technology and its applications in education will be distributed equitably and sufficiently throughout Texas.

* Statewide integrated telecommunications systems will be established.

* Professional staff employed in and entering public education will be skilled in using technology for instruction and management.

* Effective integration of technology in education will continually increase.

* Applications for education of emerging technology that meet state standards will be developed and marketed at competitive prices.

* A Long-Range Plan for Technology for the first decade of the 21st century will be prepared for implementation.

Budget. The appropriation requested to initiate implementation of the plan during the first biennium is $16.65 million.

Status of the Plan (March 1989). The above actions that require appropriations and/or legislative authorization are coalesced in the Plan into specific requests to the Texas Legislature. Major components of the request include:

* Authorization of the appropriation of $16.65 million to establish the electronic information transfer system; to expand integrated telecommunications systems; to establish the Center for Educational Technology; to establish demonstration programs; to expand staff and establish Technology Preview Centers at regional education service

centers; and to provide operating funds for the Texas Education Agency.

* Creation of a Technology Equipment Allotment.

* Creation of an Instructional Television Allotment.

* Authorization of demonstration flexibility programs in district uses of technology.

* Revision of arrangements with the State Purchasing and General Services Commission.

The State Board of Education included in its priority recommendations to the 71st Texas Legislature, which convened in January 1989, a request for statutory language authorizing implementation of the plan. Two bills (S.B. 650 and H.B. 2783), which differ but which embody the essence of the board's recommendations, have been filed. Committee hearings and staff discussions to coordinate these bills with a profusion of others that relate to telecommunications are anticipated. Thereafter: the appropriations process.

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